THE LARGER RELATIONS OF CLIMATE AND CROPS IN THE UNITED STATES.[1]

By Prof. R. DeC. Ward, Harvard University.

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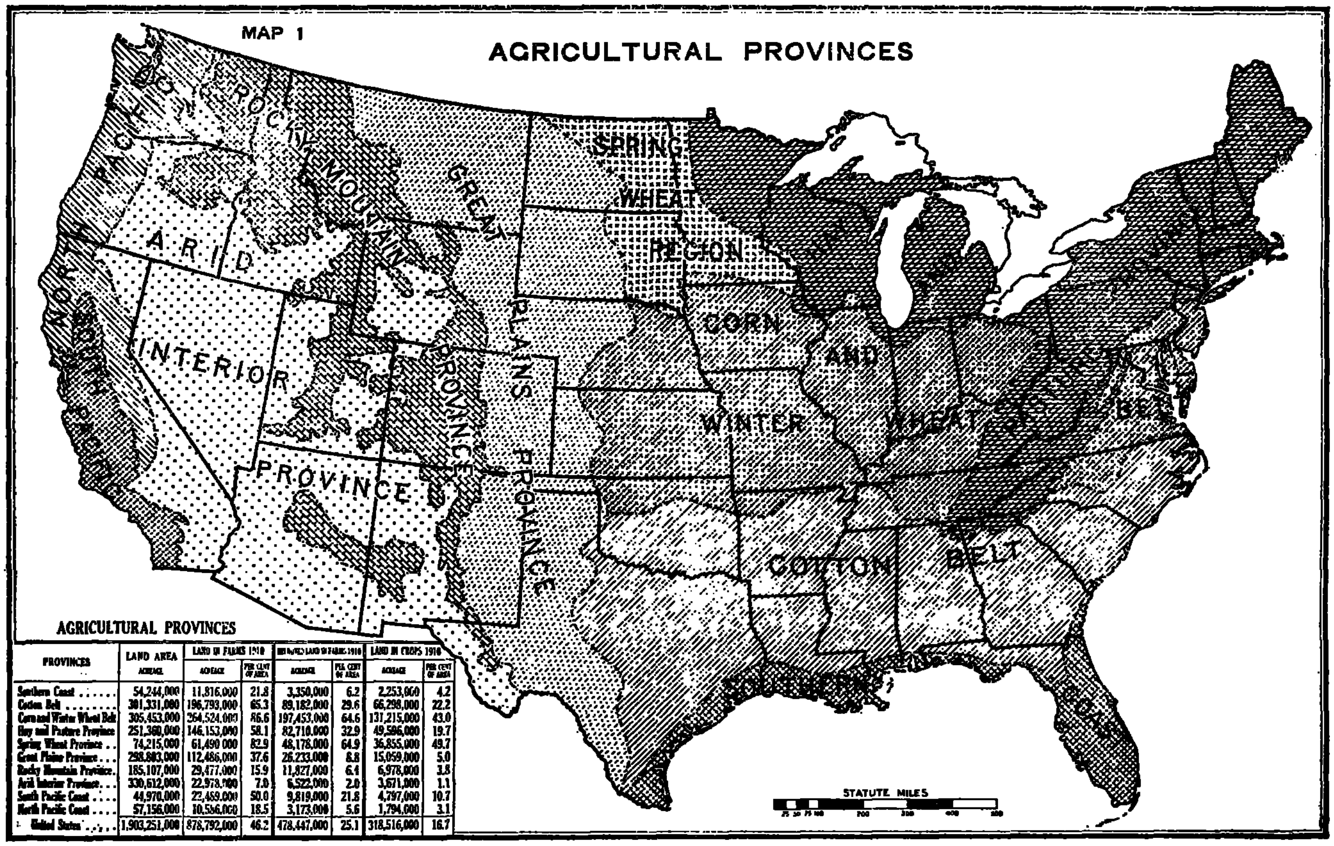
With their wide range of climatic types, and their great variety of vegetable products, the United States offer an unusually interesting field for the study of the relations between climate and crops. * * * Climate is but one of the many controls which determine the present geographical distribution of the staple crops, but it is fundamental. Soil, the kind of seed, methods of cultivation, population, transportation, and other factors play a part in a relation which is inevitably so highly complex that great caution is necessary in the endeavor to express it in terms of one, or more, of the climatic elements.

The map here reproduced (fig. 1) is based primarily upon the distribution of the principal crops and upon the types of farming. The country is conveniently divided into two major divisions, separated by * * * the "dry farming-line." The half of the country east of this line has sufficient rain in normal years, and produces annual summer crops cultivated by ordinary farming methods. The western half of the United States, with generally inadequate rainfall (except on the north Pacific coast and in parts of California and of the northern Rocky Mountain district), contains only limited areas where ordinary farming of the eastern type can be practiced. The West is a region of irrigation, of dry farming or grazing. In special localities winter crops are raised. Both eastern and western halves may be subdivided into five agricultural provinces. The eastern half is essentially a lowland, interrupted toward its eastern margin by the plateaus and mountains of the Appalachian system, all of moderate elevation. Hence latitude, i. e., temperature, and not altitude [except in the Appalachians] is the dominant climatic control. The agricultural provinces therefore have a general east and west extension.

West of the Great Plains, on the other hand, the topography is very varied, with high mountain ranges extending in a general north and south direction. The agricultural provinces also extend roughly north and south. Rainfall is here the critical factor, and rainfall is largely determined by the topography. Under the control of the varying conditions of rainfall, temperature, altitude, soil, and economic factors, the crops in this western section are very varied, and often extremely localized. There are no great belts distinguished by certain dominant crops as in the East. A detailed map of crop distribution in the West is therefore very patchy, the patches usually corresponding to districts of local irrigation. The names of the agricultural provinces in the West are not derived from the characteristic crops, but from location or topography.

If we consider each of the major crops it is found that the boundaries of the most important regions where they



PROVINCES	LAND AREA	LAND IN FARMS 1910		IMPROVED LAND IN FARMS 1910		LAND IN CROPS 1910	
	ACREAGE	ACREAGE	PER CENT OF AREA	ACREAGE	PER CENT OF AREA	ACREAGE	PER CENT OF AREA
Southern Coast	54,244,000	11,816,000	21.8	3,350,000	6.2	2,253,000	4.2
Cotton Belt	301,331,000	196,793,000	65.3	89,182,000	29.6	66,298,000	22.2
Corn and Winter Wheat Belt	305,453,000	264,524,000	86.6	197,453,000	64.6	131,215,000	43.0
Hay and Pasture Province	251,360,000	146,153,000	58.1	82,710,000	32.9	49,596,000	19.7
Spring Wheat Province ..	74,215,000	61,490 000	82.9	48,178,000	64.9	36,855,000	49.7
Great Plains Province ...	298,803,000	112,486,000	37.6	26,233,000	8.8	15,059,000	5.0
Rocky Mountain Province.	185,107,000	29,477,000	15.9	11,827,000	6.4	6,978,000	3.8
Arid Interior Province...	330,612,000	22,978,000	7.0	6,522,000	2.0	3,671,000	1.1
South Pacific Coast	44,970,000	22,459,000	50.0	9,819,000	21.8	4,797,000	10.7
North Pacific Coast	57,156,000	10,586,000	18.5	3,173,000	5.6	1,794,000	3.1
United States	1,903,251,000	878,792,000	46.2	478,447,000	25.1	318,516,000	16.7

FIG. 1.—Agricultural provinces of the United States. Yearbook U. S. Dept. Agr., 1915, p. 335.

[1] Based largely on a study of the following publications: "Geography of the World's Agriculture," by V. C. Finch and O. E. Baker, Office of Farm Management, Washington, D. C., 1917; "A Graphic Summary of American Agriculture," by M. Smith, O. E. Baker, and R. G. Hainsworth, Yearbook U. S. Dept. Agr., 1915, pp. 329-403; "A Graphic Summary of World Agriculture," by V. C. Finch, O. E. Baker, and R. G. Hainsworth, Yearbook U. S. Dept. Agr., 1916, pp. 531-553.

are cultivated coincide more or less closely with certain isotherms of average seasonal temperature, or with certain isohyets of average annual rainfall. This correspondence does not necessarily mean that the given seasonal temperatures or annual rainfalls are the factors responsible for the locations of these boundaries, although undoubtedly it is the case that certain temperature features, such as the occurrence of low temperatures unfavorable for the growth of the crop, and certain rainfall characteristics, such as the seasonal distribution of rainfall, the frequency of droughts, or the frequency of occurrence of rains of different intensities, all of which are related to the average conditions coinciding with the crop boundaries, are the true controlling factors.

Corn.—* * * The area of maximum production is limited by a mean summer temperature of 70° to 80° F.; a mean night temperature exceeding 58° F.; an average growing (frostless) season of about five months (150 days), and an annual rainfall of 25 to 50 inches or more. Nearly all the corn is south of the mean summer isotherm of 66°, and of a line showing a mean night temperature during the summer months of 55°. Because of its temperature requirements, corn can not be profitably cultivated far north, or at considerable altitudes in the West. Extended corn cultivation is fairly well limited in the West by the mean summer rainfall line of 8 inches, but if the summer temperature is over 70°, and evaporation is not excessive, an even smaller summer rainfall will suffice. * * * In the West, as a whole, the rainfall is too light and the nights are too cool for corn. * * * Where the growing season is too short, or the temperature too low, corn is widely grown for silage. The summer rainfall, however, must be about 7 inches or more. Corn is a very profitable crop. It therefore tends to become dominant in regions where it finds the climate best suited to it, especially if the competing crops require farm labor at the same time. Corn is widely grown in the "cotton belt." The climatic range of cotton, however, is much more limited than that of corn, and cotton is a tremendously profitable crop, so corn there becomes subordinate. * * *

Wheat.—* * * The mean winter isotherm of 20° is a general limiting control on the north, although some winter wheat grows in the Red River Valley, where the winter temperatures are a good deal lower. * * * Between 15 and 30 inches of rain are found where the wheat production is densest. Some wheat is, however, grown by dry farming where the mean annual rainfall is 10 inches or even less. * * * The damaging effects of rusts in the moister regions, especially if the wheat can not be made to mature early in the summer; the likelihood of rain interference with harvesting operations; competition with cotton, and other factors limit the great winter wheat region on the south at about the northern edge of the cotton belt.

* * * A mean summer temperature of about 58° F. determines the northern boundary of spring wheat. This isotherm [in the United States] is found only in the mountain area of the West. * * * With respect to the chemical composition and quality of wheat, climate has more influence than soil, but soil has a marked influence upon the permanency of wheat production in any given area.

Cotton.—* * * The mean summer isotherm of 77° F. marks fairly closely the northern, and a mean annual rainfall of 23 inches the western boundary. The average length of the growing (frostless) season is 200 days (Apr. 1 to Nov. 1), and in four-fifths of the years is more than 165 days. Warm and moderately moist weather is most favorable from April to August, while cool and dry autumns improve the quality and facilitate the picking. Too much rain in the picking season injures the lint. Thus, an important climatic element in cotton picking is the way in which the spells of dry weather are grouped. * * *

Oats, barley, and rye.—A cool, moist climate is the best for oats. The winter-oat region of the East, where most of the crop is fall-sown, is in the southeastern section, its northern boundary being about along the mean winter isotherm of 35° F.[1]

In the most important barley districts no month during the growing season has a mean temperature over 75°. In high parts of Colorado, barley grows * * * with much lower temperatures and not infrequent frosts. In southeastern California barley is raised where the mean summer temperatures are over 90°. The chief barley regions of the country have somewhat less than 35 inches of rain a year. In California, the mean annual rainfall is less than 10 inches.

Where rye production is greatest the mean summer temperature is about 70° * * *

Hay, forage, and pasture.—Hay, forage, and pasture crops are very widely distributed, for winter cold or insufficient rainfall necessitate a supply of forage in all sections except the Gulf and the north Pacific coasts, and their many different varieties are adapted to a wide range of climates. In general, the cooler, wetter, rougher, less fertile parts of the country are devoted to these crops. There is, however, much hay and forage raised in rotation with other crops, especially in the corn and winter-wheat belt. Alfalfa, although grown under a great variety of conditions, does best where the summers are not rainy, and in the southwest. Less than 6 per cent of it comes from east of the Mississippi.* * * Timothy and clover are not only better adapted to the crop rotation systems of the East, but also do not suffer much from winter-killing. The principal forage crops of the hot and droughty parts of the Great Plains are the Kafir corn and milo maize. The bulk of the crop is within the rainfall lines of 15 and 30 inches. The northern limit of Kafir is the mean summer isotherm of about 75°; that of milo, about 70°.

Sugar.—Sugar cane raised commercially for sugar comes almost entirely from the lower delta of the Mississippi River, in Louisiana, where the rainfall is heavy (50 to 65 inches), and destructively low temperatures are rare. Sugar beets, on the other hand, come from the northwestern margin of the corn and winter wheat belt, and from local areas in the West, especially in southern California. Profitable use of beets for sugar is, on the whole, limited to regions whose mean summer temperatures are below 72°.

Rice.—Rice needs so much water that it is grown mostly on the moist river plains of the southern coastal plain and Mississippi flood-plain and delta lands. In Louisiana, rice needs water amounting to 0.5 inch of rainfall daily for three months, or 45 inches. Half of this water is supplied by irrigation.

Vegetables.—Vegetables are raised as near to market as the climatic conditions permit. In many cases hothouse vegetables of the North can compete successfully with the early vegetables grown in the usually frost-free southern coast.

Fruits.—Temperature is usually the controlling factor in the distribution of the different kinds of fruits. The citrus fruits come from the Gulf coast region and

[1] See fig. 40, p. 35, Geography of the World's Agriculture. [By V. C. Finch and O. E. Baker, Office of Farm Management, U. S. Dept. Agr., Washington, D. C., 1917.]

California, where killing frosts are rare enough to make the culture profitable in the long run, especially if orchard heating is practiced at critical times. Peaches are raised extensively in the South and on the leeward shores of Lakes Michigan, Huron, and Erie, where killing winter temperatures and frosts after flowering are infrequent. Apples, being hardier, are raised farther north, though in apple culture, valley slopes and leeward (eastern) shores are favored. Pears and cherries are intermediate between peaches and apples.

Live-stock.—Live-stock raising is controlled mostly by rainfall, though the temperature limitations imposed on the distribution of field crops enters also. Hogs thrive where the corn grows; dairy cows are most numerous farther north, where there is the corn silage. Cattle are raised in the general hay and pasture regions, and, in relative importance for the regions involved, hold sway particularly where field crops can not well be raised. In the arid parts of the West the cattle can get some sustenance on the plains and mountains, but the forage (mostly alfalfa) from the irrigated patches must supplement this generally meager and discontinuous supply. In the driest parts, sheep can live where cattle can not.

It is usually obvious that the climate is essentially the basis for the general type of farming at any place. There is the "wet farming" of the eastern half of the country, where the rainfall is generally sufficient for the crops that are to be raised, and where, therefore, the temperature determines what can be raised, and the topography and soil limit the local distribution. The dry farming of the Great Plains and of other parts of the West relies on conservation of what rain there is by limiting evaporation from the soil. In some places, as in eastern Washington, two years' rainfall is needed for one good crop of wheat. The irrigation farming of the arid parts of the West is necessitated by the dryness of the lowlands, but is rendered possible by the rainfall precipitated on the mountains which keep the moisture from reaching the valleys to leeward.

A comprehensive bibliography closes Prof. Ward's paper.—*C. F. B.*

MINIMUM TEMPERATURES SUSTAINED BY APRICOTS DURING MARCH, 1919, IN THE PECOS VALLEY, N. MEX.

By CLEVE HALLENBECK, Observer.

[Dated: Weather Bureau Office, Roswell, N. Mex., May 17, 1919.]

It has been a matter of common observation in the semi-arid and elevated regions of the West that fruit blossoms and other tender vegetation will withstand temperatures that would kill all or nearly all growing vegetation in the lower and more humid districts of the eastern half of the United States. Whether this resistance to cold is due to elevation, humidity, soil, or some unknown factor, or to two or more of these combined, has not been determined, but it seems to be more noticeable when the moisture content of both the soil and the air is low. It has, however, frequently been observed under just the opposite conditions. For example, the apples in the Pecos Valley were, when in full blossom, subjected to a snowstorm lasting 15 hours, during which the temperature was continuously below freezing, and below 30° in portions of the orchard district for several hours. Nevertheless, no noticeable damage was sustained, either to fruit or to young truck crops. This was on April 8, 1919, and the same thing has occurred in previous seasons, having once before (1917) been observed by the writer.

The following data illustrate a remarkable case of resistance to temperatures below freezing after a period of low atmospheric humidity:

Date.	Minimum temperature.	State of apricots.
1919.	°*F.*	
Mar. 1	31	Buds showing pink.
2	28	
3	27	Blossoms opening.
4	29	
5	19	30 per cent of blossoms open.
6	27	
7	30	50 per cent of blossoms open.
8	29	
9	27	
10	28	
11	18	Trees in full blossom.
12	30	
15	27	Petals falling.
16	34	
18	27	Petals nearly all off.
19	29	
23	....	Fruit swelling.

On March 25 a thorough examination of the trees at different elevations showed less than 7 per cent of the fruit dead or injured; that is, over 93 per cent of the blossoms were developing sound, uninjured fruit. It is not certain that the dead and injured fruit was due to the cold, as normally, under any conditions, a part die and fall off at this stage of development.

It will be noticed that the blossoms were subjected to daily minimum temperatures below freezing during the entire time that the blossoms were opening, with a temperature 14° below freezing when in full blossom.

The temperature records were made by a Weather Bureau minimum thermometer and a thermograph in a cotton region shelter about 80 yards from the nearest trees. During the period under discussion minimum temperatures 1 inch above the surface of the ground averaged 1.4° F. higher, and at an elevation of 24 feet, 0.9° F. higher, than in the shelter.

This substation was in charge of the writer, who personally made the observations tabulated above.

NOTES.

There is some discussion of this subject in Bulletin 89 of the New Mexico Agricultural Experiment Station, 1913–14, by F. Garcia and J. W. Rigney, "Hardiness of fruit buds and flowers to frost." Although other observers have shown that 31° is the danger point for peaches and 28° that for apples, there are differences with different stages of growth, the young fruit being the most tender. While 26.5° to 27° is often detrimental to young fruit, 26° is said to be the critical temperature, though 24° sometimes has little effect. The factors of greatest importance are the degree, duration, and time of day of the greatest cold. When the lowest temperature occurs just before sunrise, the effect is worst.

W. H. Chandler, in an extensive contribution, "The killing of plant tissue by low temperature" (Mo. Agr. Exp. Sta., Research Bull. No. 8, December, 1913, pp. 143–309), gives 22° to 25° or 26° as the killing temperature for young peach flowers, and 29° to 30° as that for older ones and young fruit. This work contains a chart showing maximum and minimum temperatures preceding freezing of fruit buds; also, an extensive bibliography. For a general discussion and bibliography of "Frost and the growing season," by W. G. Reed, see Atlas of American Agriculture, advance sheets 2, Part II, section 1, 1918; also, "A selected [annotated] bibliography of frost in the United States," by W. G. Reed and C. L. Feldkamp, Monthly Weather Review, 1915, 43:512–517.